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DECLARATION

I, Manami Enomoto, a staff member of TAIYO, NAKAJIMA & KATO, Seventh Floor, HK-Shinjuku Bldg., 3-17, Shinjuku 4- chome, Shinjuku-ku, Tokyo 160-0022, Japan, do hereby declare that I am well acquainted with the English and Japanese languages and I hereby certify that, to the best of my knowledge and belief, the following is a true and correct translation made by me into the English language of the documents in respect of Japanese Patent Application No. 9-21591 that was filed on 4th February 1997 in the name of TOYOTA JIDOSHA KABUSHIKI KAISHA.

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[TITLE OF THE INVENTION]

ROAD-TO-VEHICLE COMMUNICATION DEVICE

[CLAIMS]

[Claim 1] A road-to-vehicle communication device comprising:

road-side control means being located at a road side, including road-side communication means provided for intercommunication of information with vehicle-mounted communication means, and also including first encryption means for encrypting transmitted information and decoding received information, with a first electronic key;

information control means including information transfer means which stores therein user information regarding at least one of a vehicle and a user and through which information is mutually transferred with respect to the vehicle-mounted communication means, and also including second encryption means for encrypting output information and decoding input information, with a second electronic key; and

vehicle-mounted control means being installed on a vehicle side, including vehicle-mounted communication means provided for intercommunication of information

with respect to the road-side communication device and for mutual transfer of information with respect to said information control means, and also including third encryption means which, during the communication of information, encrypts transmitted information and decodes received information with the first electronic key, and which during the transfer of information, encrypts output information and decodes input information with the second electronic key.

[Claim 2] A road-to-vehicle communication device according to claim 1, wherein each group of said first encryption means and the road-side communication means, said second encryption means and the information transfer means, and said third encryption means and the vehicle-mounted communication means are provided on the same substrate.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field of the Invention]

The present invention relates to a road-to-vehicle communication device, and particularly to a road-to-vehicle communication device which effects communication

processing between a vehicle-mounted communication device and an on-road apparatus installed on a road side.

[0002]

[Prior Art]

In recent years, an automatic toll collecting system has been developed which utilizes a toll pre-paid type card or a toll post-payment type card to receive charges for using charged facilities, for example, to receive a toll charged on a toll road. In the automatic toll collecting system, on-road apparatuses with antennas, each of which serves as an interrogator for making inquiries with respect to a vehicle for information in order to collect tolls automatically at entrance and exit gates of the toll road, are provided on the road side, and each of vehicle-mounted apparatuses for road-to-vehicle communications (hereinafter referred to as "vehicle-mounted apparatuses") with antennas, each of which serves as a responder for responding to the information, with respect to which an inquiry was made is mounted on the vehicle, whereby the information is transferred by radio communications between the vehicle-mounted apparatus and the on-road apparatus.

[0003]

As described above, in order to transfer the information between the vehicle-mounted apparatus and the on-road apparatus, toll information or vehicle information about a vehicle, and information about a user must be stored. For this reason, an IC card in which a large quantity of data can be stored may be used with information being written therein.

[0004]

However, as described above, when the information is transferred between the vehicle-mounted apparatus and the on-road apparatus or when the information is transferred to and received from the IC card, the information is used with a form thereof left unchanged. As a result, there exists a problem that a person not intended by a user can easily disclose contents of the information.

[0005]

Accordingly, there has been proposed an electronic identification system in which secrecy is kept by identifying that a transmitted secret code such as an inherent code coincides with at least one of a plurality of predetermined secret codes, thereby resulting in

improvement of security (see Japanese Patent Application Laid-Open (JP-A) No. 6-511097).

[0006]

[Problems to be Solved by the Invention]

However, in a conventional electronic identification system, only one kind of secret code is assigned to a user, and therefore, secret codes must be set correspondingly to the number of users so as to identify a great number of users. For this reason, in a road-to-vehicle communication device in which information is transferred to and received from each of a great number of users, the load on the device increases. Further, only one kind of secret code is assigned to a user, and therefore, when the secret code leaks out, the security of a system used by the user, namely, of the road-to-vehicle communication device, deteriorates.

[0007]

In view of the above-described circumstances, an object of the present invention is to provide a road-to-vehicle communication device, that can improve security using a simple structure and in a simple manner.

[0008]

[Means for Solving the Problems]

In order to achieve the above-described objects, the invention set forth in claim 1 is a road-to-vehicle communication device comprising: road-side control means being located at a road side, including road-side communication means provided for intercommunication of information with vehicle-mounted communication means, and also including first encryption means for encrypting transmitted information and decoding received information, with a first electronic key; information control means including information transfer means which stores therein user information regarding at least one of a vehicle and a user and through which information is mutually transferred with respect to the vehicle-mounted communication means, and also including second encryption means for encrypting output information and decoding input information, with a second electronic key; and vehicle-mounted control means being installed on a vehicle side, including vehicle-mounted communication means provided for intercommunication of information with respect to the road-side communication device and for mutual transfer of information with respect to said information control means, and also including third encryption means which, during the communication of information, encrypts transmitted information and

decodes received information with the first electronic key, and which during the transfer of information, encrypts output information and decodes input information with the second electronic key.

[0009]

The invention set forth in claim 2 is a road-to-vehicle communication device according to claim 1, wherein each group of said first encryption means and the road-side communication means, said second encryption means and the information transfer means, and said third encryption means and the vehicle-mounted communication means are provided on the same substrate.

[0010]

According to the invention of claim 1, information is mutually communicated between the road-side communication means of the road-side control means and the vehicle-mounted communication means of the vehicle-mounted control means. Further, information is mutually transferred between the vehicle-mounted communication means of the vehicle-mounted control means and the information transfer means of the information control means.

[0011]

During the communication of information, the road-side control means uses the first encryption means, with the first electronic key, to encrypt transmitted information to be transmitted to the vehicle-mounted control means and to decode received information from the vehicle-mounted control means. Further, the vehicle-mounted control means uses the third encryption means, with the first electronic key, to encrypt transmitted information to be transmitted to the road-side control means and to decode received information from the road-side control means. Accordingly, information can be encrypted using the first electronic key so as to be mutually communicated between the road-side control means and the vehicle-mounted control means, and therefore, the secrecy of information is maintained and the security thereof is thereby protected.

[0012]

During the transfer of information, the vehicle-mounted control means uses the third encryption means, with the second electronic key, to encrypt output information and to decode input information. The information transfer means stores therein user information regarding at least one of a vehicle and a

user. When the user information is outputted to the vehicle-mounted control means, the information transfer means uses the second encryption means, with the second electronic key, to encrypt, as output information, the user information and to decode input information from the vehicle-mounted control means. Accordingly, information can be encrypted using the second electronic key so as to be mutually transferred between the vehicle-mounted control means and the information transfer means, and therefore, the secrecy is maintained and the security is thereby protected.

[0013]

As described above, secrecy is independently maintained using different electronic keys respectively for the communication of information and for the transfer of information, and therefore, the security of the road-to-vehicle communication device can be improved. Further, since secrecy is independently held, leakage of information can be restrained to the minimum until the secrecy becomes clear.

[0014]

The above-described first, second, and third encryption means are each that which maintains secrecy,

and therefore, so long as these encryption means are each made clear, the secrecy can be made clear. Accordingly, as described in claim 2 as well, by providing each of the first encryption means and the road-side communication means, the second encryption means and the information transfer means, and the third encryption means and the vehicle-mounted communication means on the same substrate, on the same chip, for example, decoding such as analysis becomes difficult and the security of the road-to-vehicle communication device can be improved.

[0015]

[Embodiments]

Embodiments of the present invention will hereinafter be described in detail with reference to the accompanying drawings. The present embodiments each show that the present invention is applied to an automatic toll receiving system for automatically receiving a toll from each of vehicles running on a toll road or the like.

[0016]

In the automatic toll receiving system, information is transferred between an apparatus mounted on a vehicle and an on-road apparatus having antennas provided at ground portions of an entrance gate, an exit

gate, and the like through radio communications to thereby determine a traffic section (route) over which the vehicle has been driven and the type of the vehicle and automatically accept a traffic toll or the like without stopping the vehicle at the entrance and exit gates.

[0017]

As shown in Fig. 1, an automatic toll receiving system of the present embodiment is structured to include the on-road apparatus 10 provided on the road side and the vehicle-mounted apparatus 30 mounted on a vehicle. Information is mutually transferred between the on-road apparatus 10 and the vehicle-mounted apparatus 30 by radio communications. An on-road apparatus communicating with the vehicle-mounted apparatus 30 includes antennas for transmitting and receiving various information and is disposed in each of an entrance gate of a toll road, a mid-route thereof, and an exit gate. The on-road apparatus 10 includes a memory 28 (see Fig. 4) in which the electronic key A is stored, and the vehicle-mounted apparatus 30 includes the storage circuit 48 (see Fig. 3) in which electronic keys A, B, and C are stored, as will be described in detail later. When information is mutually transferred between the

on-road apparatus 10 and the vehicle-mounted apparatus 30 by radio communications, transmitted information is encrypted and received information is decoded, using the electronic key A.

[0018]

The above-described encryption and decoding can be provided using a secret key encryption system (for example, Data Encryption Standard (DES)).

[0019]

The IC card 62 (described in detail later) in which various information is stored is detachable from the vehicle-mounted apparatus 30. Information is mutually transferred between the vehicle-mounted apparatus 30 and the IC card 62. The IC card 62 includes the memory 70 (see Fig. 5) in which the electronic key B is stored. When information is transferred between the vehicle-mounted apparatus 30 and the IC card 62, transmitted information is encrypted using the electronic key B and received information is decoded.

[0020]

The type of a vehicle on which the vehicle-mounted apparatus 30 is mounted or vehicle information such as

an ID number may be written in the vehicle-mounted apparatus 30. The vehicle information is written using an information writing device 76. The information writing device 76 includes a memory 84 in which the electronic key C is stored (see Fig. 5). When the vehicle information is transferred between the vehicle-mounted apparatus 30 and the information writing device 76, the vehicle information is encrypted using the electronic key C and received information is decoded.

[0021]

Next, the vehicle-mounted apparatus 30 and the on-road apparatus 10 communicating with the vehicle-mounted apparatus 30 will be described in detail. The present embodiment will be described with an on-road apparatus provided in the mid-route 200 being given as an example. Further, for simplifying explanation, the mid-route antenna 218 provided for radio communication with the vehicle 90 traveling along the lane 202 and the mid-route antenna control device 232 are used. A vehicle-mounted battery (not shown) is connected to the vehicle-mounted apparatus 30.

[0022]

As shown in Fig. 2, in the mid-route 200 located immediately before or after a branching point of a toll road, two lanes, the lane 202 and a lane 204, are provided side by side between a ground 208 and a ground 214. An arch 216 is disposed between the ground 208 and the ground 214 in such a manner as to extend over the lanes 202 and 204. Route recognizing antennas 218, 220, and 222 are disposed on the arch 216. The route recognizing antenna 218 is located above the lane 202 for radio communication with a vehicle traveling along the lane 202. The route recognizing antenna 222 is located above the lane 204 for radio communication with a vehicle traveling along the lane 204. The route recognizing antenna 220 is disposed substantially at an intermediate point between the route recognizing antennas 218 and 222 such that it is located above a centerline 206 between the lanes 202 and 204, for radio communication with a vehicle running so as to straddle the boundary between the lanes 202 and 204.

[0023]

A route control center 230 equipped with the route recognizing antenna control device 232 is disposed on the ground 214. The route recognizing antennas 218, 220, and 222 are connected to the route recognizing antenna control device 232.

[0024]

In the above-described mid-route 200, the route recognizing antenna control device 232 transmits route passage information, which represents the kind of route a vehicle 90 traveled on a toll road, to the vehicle-mounted device 30 mounted on the vehicle 90, via the route recognizing antenna. The route recognizing antenna control device 232 can be connected to a central computer for collectively controlling a running state of the vehicle on the toll road. A recovery gate can be disposed at the mid-route 200 so as to write the route information indicating a mid-route into the vehicle-mounted apparatus using the IC card 62. The recovery gate is provided with an IC card read/write device in which the IC card 62 is removably mounted. The IC card read/write device is connected to the central computer. The recovery gate may be disposed at a parking area or a service area.

[0025]

Meanwhile, at the entrance gate that is another on-road apparatus, entrance information of the toll road is transmitted to the vehicle-mounted apparatus 30 mounted on the vehicle. Further, at the exit gate, exit information which indicates an exit gate is transmitted

to the vehicle-mounted apparatus 30 mounted on a vehicle, and for example, traffic charges or tolls corresponding to the section (route) run by the vehicle or to the type of vehicle are automatically received.

[0026]

This entrance information and exit information can be transferred by an operator via an IC card. For example, when a communication error occurs, at the recovery gate for writing in data such as the entrance information which indicates an entrance gate using the IC card or for reading out data stored in the vehicle-mounted apparatus, the IC card read/write device to which the IC card 62 can be attached and detached is used to enable execution of transfer of the entrance and exit information. Codes such as numbers or the like, which are in advance assigned respectively to positions of toll roads, may be used for the entrance information and route information.

[0027]

As shown in Fig. 3, the vehicle-mounted apparatus 30 includes the receiving antenna 32 for receiving a data signal transmitted from the on-road apparatus. The receiving antenna 32 demodulates a received modulated wave and is connected to a demodulation circuit 34 for

obtaining the data signal. The demodulation circuit 34 can also obtain a carrier wave of an electric wave transmitted from the on-road apparatus and may be connected to the transmission circuit 50. The demodulation circuit 34 is connected via the data signal receiving circuit 44 to the signal processing circuit 46 including a microcomputer. The microcomputer of the signal processing circuit 46 stores therein a processing program and the like, as will be described later.

[0028]

The storage circuit 48 is connected to the signal processing circuit 46. The storage circuit 48 in advance stores therein the electronic keys A, B, and C. Further, the information writing device 76 can be connected to the signal processing circuit 46 and information regarding a vehicle-mounted apparatus is stored in the storage circuit 48. Namely, when the vehicle-mounted apparatus is mounted on a vehicle, a vehicle number (the number recorded on a number plate) serving as an ID code is stored in the storage circuit 48 by the information writing device 76 and information regarding the type of the vehicle on which the vehicle-mounted apparatus is mounted is also stored in the storage circuit 48. Further, when the IC card 62 is inserted, information about the balance

(such as information about the money left and the result of updating of the balance at the time that the IC card 62 is used within a service area at which the vehicle stops midway) of the IC card 62 is stored in the storage circuit 48. Further, when the vehicle has passed through an entrance gate, a vehicle-type code detected at the entrance gate and entrance information (entrance number, date and time of passage of the vehicle, and the like) are stored in the storage circuit 48. When the vehicle has passed through a mid-route (check barrier), check barrier information (check barrier number and date and time of passage of the vehicle) corresponding to the passed check barrier is stored in the storage circuit 48. And when a communication error arises, communication error information (type of error, positions at which the error occurred (type of gate, gate number, antenna number, and the like), date and time of occurrence of the error, the number of times that an error occurs, and the like) or the like is stored in the storage circuit 48.

[0029]

The transmission circuit 50 for transmitting, as a response signal, a data signal including an ID code, and the like is connected to the signal processing circuit 46. The transmission circuit 50 is connected to a

transmission antenna 52. The vehicle-mounted apparatus 30 modulates a carrier wave obtained by demodulating the modulated wave received at the receiving antenna 32, based on a data signal from the signal processing circuit 46 and can send back the modulated carrier wave through the transmission antenna 52. Meanwhile, the transmission antenna 52 is provided so as to function as a transmitting/receiving antenna. An unmodulated carrier wave transmitted from the on-road apparatus is received by the transmission antenna 52, and thereafter, the unmodulated carrier wave may be modulated by the transmission circuit 50 based on the data signal from the signal processing circuit 46, so as to be sent back via the transmission antenna 52.

[0030]

Further, the IC card read/write device 60 for reading data from the IC card 62 inserted therein and writing data into the IC card 62 is connected to the vehicle-mounted apparatus 30. The limit switch 58 for mechanically detecting the insertion of the IC card 62 is provided in the IC card read/write device 60. Whether the IC card has been inserted into the IC card read/write device 60 may be optically detected by determining, using a photo-interrupter composed of a light-emitting element

and a light-receiving element disposed opposite each other, whether light is cut off by the inserted IC card.

[0031]

The display 54 comprised of an LCD or CRT for displaying whether the IC card has been inserted, the balance, and the like thereon, and the ten key 56 for inputting a signal to the signal processing circuit 46 are each connected to the signal processing circuit 46.

[0032]

As shown in Fig. 4, the on-road apparatus for a vehicle traveling along the lane 202 is comprised of the mid-route antenna 218 and the mid-route antenna control device 232. The mid-route antenna 218 is comprised of the transmission antenna 22 and the receiving antenna 26. The mid-route antenna control device 232 has the signal processing circuit 12 including a microcomputer. The microcomputer stores therein a processing program which will be described later. The signal processing circuit 12 can be connected to a central computer 400 (not shown). The signal processing circuit 12 is connected to the transmission circuit 14 which generates a data signal including an instruction (a communication requesting signal). The transmission circuit 14 is connected via

a mixer 18 to the transmission antenna 22. A carrier wave generation circuit 20 which generates a carrier wave having a predetermined frequency is connected to the mixer 18. The mixer 18 mixes a signal inputted from the transmission circuit 14 and a carrier wave inputted from the carrier wave generation circuit 20 and modulates the carrier wave inputted from the carrier wave generation circuit 20 with the signal inputted from the transmission circuit 14. Further, the modulated wave is transmitted as a radio wave from the transmission antenna 22.

[0033]

Connected to the carrier wave generation circuit 20 is the receiving circuit 24 which fetches a data signal from the modulated wave modulated and sent back from the vehicle-mounted apparatus 30 and received by the receiving antenna 26. The receiving circuit 24 is connected to the signal processing circuit 12. Further, the receiving circuit 24 is connected to the carrier wave generation circuit 20 and a carrier wave transmitted for comparison of the carrier wave included in the signal sent back from the vehicle-mounted apparatus 30 is inputted thereto.

[0034]

Other structures in the mid-route 200 are the same as the above-described ones, and therefore, descriptions thereof will be omitted. Further, respective antennas and antenna control devices at an entrance gate 100 and an exit gate 300 are substantially the same in structure as those referred to the above, and therefore, descriptions thereof will be omitted.

[0035]

Further, in the above-described vehicle-mounted apparatus and on-road apparatus, an antenna comprised of the transmitting and receiving antennas separated from each other is used. However, a transmission/reception type antenna may be used.

[0036]

As shown in Fig. 5, the IC card 62 which can be inserted in the vehicle-mounted apparatus 30 is comprised of a microcomputer including the CPU 64, the RAM 66, the ROM 68, the memory 70, and the input/output (I/O) port 72, which are connected by the bus 74 so as to allow transfer of a command or data therebetween. The memory 70 is used for storage of the electronic key B and various information. Further, the ROM 68 stores therein a processing routine which will be described later. The

input/output port 72 can be connected to the vehicle-mounted apparatus 30 or to the IC read/write device 60. Further, although not illustrated, the IC card 62 is provided with a power source circuit so as to supply a power source constantly.

[0037]

The above-described IC card can store, as various information, information regarding the vehicle-mounted apparatus such as a card number, balance information, information about utilization details (entrance gate number, exit gate number, toll, date and time of utilization, and the like), and also can store a certified key code for having a card correspond to the vehicle-mounted apparatus, namely, recording the electronic key B.

[0038]

Further, there can be used, as the IC card, various cards, for example, a memory card such as an LSI card, a magnetic card, a hologram card on which information can be optically recorded and reproduced, or a magneto-optical card on which information can be magneto-optically recorded and reproduced.

[0039]

The information writing device 76 for writing the information regarding the vehicle-mounted apparatus in the above-described vehicle-mounted apparatus 30 can be connected to the vehicle-mounted apparatus 30 and is comprised of a microcomputer including a CPU 78, a RAM 80, a ROM 82, a memory 84, and an input/output (I/O) port 86, which are connected by a bus 88 so as to allow transfer of a command or data. The memory 84 is used for storage of the electronic key C and various information. The ROM 82 stores therein a processing routine, which will be described later. The input/output port 86 can be connected to the vehicle-mounted apparatus 30.

[0040]

Next, an operation of the present embodiment will be described.

First, a process for writing vehicle information in the vehicle-mounted apparatus 30 will be described.

[0041]

Fig. 6 shows a process routine in the information writing device 76 for writing vehicle information in the vehicle-mounted apparatus 30. When the process is executed, in step 100, vehicle information such as the

type of vehicle on which the vehicle-mounted apparatus 30 is mounted, an ID number, and the like, which is to be written in the vehicle-mounted apparatus 30, is set. In the subsequent step 102, the electronic key C is read and the set vehicle information is encrypted by the electronic key C. In the subsequent step 104, the encrypted vehicle information is outputted to the vehicle-mounted apparatus 30 (see an output C1 in Fig. 11). The information writing device 76 thus encrypts the vehicle information to be outputted and maintains the secrecy of the information.

[0042]

Fig. 7 shows a process routine of the vehicle-mounted apparatus when the vehicle information is written therein. In step 106, the vehicle-mounted apparatus waits until information is inputted thereto, and when information is inputted, in step 108, the electronic key C is read and the inputted information is decoded by the electronic key C. In the subsequent step 110, it is determined whether the decoded information is the vehicle information. When the decoded information is not the vehicle information, it is determined that other processing is effected or false information is given (when the decision of step 110 is negative), and the

present routine ends. On the other hand, when the decoded information is the vehicle information (when the decision of step 110 is affirmative), in step 112, the decoded vehicle information is written in the storage circuit 48. As described above, in the vehicle-mounted apparatus 30, the encrypted information is decoded and it is determined whether the decoded information is the vehicle information. Accordingly, there is no possibility of the inputted information being incorrectly written in the vehicle-mounted apparatus.

[0043]

Next, intercommunication processing between the on-road apparatus and the vehicle-mounted apparatus will be described.

Fig. 8 shows in detail communication processing of the vehicle-mounted apparatus. In step 114, the vehicle-mounted apparatus waits until it receives a signal from the on-road apparatus (see a transfer A1 in Fig. 13). When the vehicle-mounted apparatus receives the signal (when the decision of step 114 is affirmative), in the subsequent step 116, the electronic key A is read and the received signal is decoded by the electronic key A. In the subsequent step 118, it is determined whether the decoded signal is an inquiry signal. When the decoded

signal is not an inquiry signal, the decision of step 118 is negative, and the process returns to step 114. When the decoded signal is an inquiry signal, the decision of the step 118 is affirmative and the process proceeds to step 120.

[0044]

In step 120, the electronic key A and the vehicle information (for example, an ID code such as an identification code which specifies a vehicle), and the vehicle information is encrypted by the electronic key A. In the subsequent step 122, with the received inquiry signal being used as a carrier wave, a modulated wave wherein the carrier wave is modulated with the encrypted vehicle information is transmitted as an inquiry signal (a transfer A2 in Fig. 13).

[0045]

Next, in step 124, the vehicle-mounted apparatus waits until it receives a signal from the on-road apparatus (a transfer A3 in Fig. 13). When the vehicle-mounted apparatus receives the signal (when the decision of step 224 is affirmative), in step 126, the received signal is decoded by the electronic key A. In the subsequent step 128, by determining whether the

decoded signal includes entrance information, it is determined whether the vehicle is presently passing the entrance gate. When the vehicle is not passing the entrance gate (when the decision of step 128 is negative), the process proceeds to step 130. When the vehicle is passing the entrance gate, in step 132, entrance gate processing (the transfer A4 to An in Fig. 13) is executed. In this entrance gate processing, in step 506, the entrance information which is an entrance gate number included in the received signal is stored in the storage circuit 48 of the vehicle-mounted apparatus 30.

[0046]

In step 130, based on a determination as to whether the decoded signal includes a mid-route code (check barrier information), it is determined whether the vehicle has passed the mid-route 200. When the vehicle has passed the mid-route 200 (when the decision of step 130 is affirmative), in step 134, mid-route processing is executed. When the vehicle has not passed the mid-route 200 (when the decision of step 130 is negative), it is determined that the vehicle has passed an exit gate, and in step 136, exit gate processing is executed.

[0047]

In this mid-route processing, mid-route information based on a mid-route code included in the decoded signal is stored in the storage circuit 48 of the vehicle-mounted apparatus 30. Further, in the exit gate processing of step 514, based on information regarding the type of vehicle stored in the vehicle-mounted apparatus, balance information stored in the IC card mounted in the vehicle-mounted apparatus, and a toll table recorded in advance in the vehicle-mounted apparatus, tolls charged on a route from the entrance gate to the exit gate with the mid-route located therebetween are calculated from the present balance, and the charged tolls are automatically collected. After the tolls have been normally collected, entrance information is cleared. In the mid-route processing or in the exit entrance processing, transfer of information indicated by the transfer A4 to An shown in Fig. 13 is carried out in accordance with the number of processes. The transfer of information to the IC card will be described later.

[0048]

As shown in Fig. 9, in step 138, an on-road apparatus located in a mid-route reads the electronic key A and encrypts an inquiry signal by the electronic key A. In the subsequent step 140, the on-road apparatus

transmits the encrypted inquiry signal (see the transfer A1 in Fig. 13).

[0049]

Subsequently, the on-road apparatus transmits the encrypted inquiry signal until it receives the response signal from the vehicle-mounted apparatus 30, and in the subsequent step 142, it is determined whether the on-road apparatus has received the signal from the vehicle-mounted apparatus 30. When the on-road apparatus has received the signal, the decision of step 142 is affirmative, and in the subsequent step 144, the signal is decoded using the electronic key A. When the on-road apparatus has not received the signal (when the decision of step 142 is negative), the process returns to step 138.

[0050]

In the subsequent step 146, it is determined whether the decoded signal is a response signal. When it is the response signal (when the decision of step 146 is affirmative), in step 148, gate information, in this case, mid-route information is encrypted using the electronic key A. In the subsequent step 150, the on-road apparatus transmits a signal including the encrypted

mid-route information and the like (see the transfer A3 in Fig. 13).

[0051]

Meanwhile, in the on-road apparatus at the entrance gate, substantially the same process as the above-described one is executed, but the on-road apparatus transmits, in place of the signal including the mid-route information and the like, a signal including an entrance gate number, which represents the entrance gate, and the like. Further, in the on-road apparatus at the exit gate 300 as well, substantially the same process as the above-described one is executed, but the toll receiving processing may be executed by a signal including an exit code representing an exit gate, and the like or by radio communications.

[0052]

In the transfer of a signal between the above-described on-road apparatus 10 and the vehicle-mounted apparatus 30, information is decoded by the electronic key A. Accordingly, the information transferred between the on-road apparatus 10 and the vehicle-mounted apparatus 30 maintains secrecy, and the security to the interception of information can be improved.

[0053]

Next, a process for the transfer of information between the IC card 62 and the vehicle-mounted apparatus 30 will be described. In the following, processing in the IC card read/write device 60 connected to the vehicle-mounted apparatus 30 will be described, and the present invention can also be applied to a case in which an IC card read/write device is independently located at a recovery gate or the like.

[0054]

Fig. 12 shows a process in the IC card 62. In step 152, it is determined whether a signal is inputted from the vehicle-mounted apparatus 30. When a signal is not inputted, the decision of step 152 is negative and the decision of step 152 is made repeatedly. On the other hand, when a signal is inputted (see a transfer B1 in Fig. 12 and the transfer B1 in Fig. 13), the decision of step 152 is affirmative, and in step 154, the IC card reads the electronic key B and decodes the inputted signal by the electronic key B. In the subsequent step 156, it is determined whether the decoded signal is a read/write request given to the IC card 62. When the inputted signal is a request other than the read/write request, the

decision of step 156 is negative, and the process returns to step 152. On the other hand, when the process effected for the IC card 62 is the request for reading and writing, the decision of step 156 is affirmative. In the subsequent step 158, it is determined whether the request is that for writing. When the request is that for writing data, the decision of step 158 is affirmative, and the process proceeds to step 160, and when the request is that for reading data, the decision of step 158 is negative, and the process proceeds to step 166.

[0055]

In step 160, a request for output of data is given to the vehicle-mounted apparatus 30 (see a transfer B2 in Fig. 12 and a transfer B2 in Fig. 13), and the data is inputted to the IC card. The inputted data is decoded in step 162 and the decoded data is written in the memory 70 in step 164.

[0056]

In step 166, the data stored in the memory 70 is read, and in the subsequent step 168, the data is encrypted by the electronic key B. In step 170, the data is outputted to the vehicle-mounted apparatus 30 (see the transfer B2 in Fig. 12 and the transfer B2 in Fig. 13).

[0057]

Accordingly, the information transferred between the vehicle-mounted apparatus and the IC card is allowed to maintain secrecy so as to improve the security with respect to the interception of the information.

[0058]

As described above, in the present embodiment, at the time of communication of information between the on-road apparatus and the vehicle-mounted apparatus and in the transfer of information between the vehicle-mounted apparatus and the IC card or between the vehicle-mounted apparatus and the information writing device, the information is encrypted or decoded using different electronic keys. For this reason, even when the secrecy of one electronic key leaks out, disclosure of the secrecy of a system can be kept to a minimum. Accordingly, the reliability of data held by each system can be improved and the load of each system can be reduced by the secrecy which is based on a small number of electronic keys.

[0059]

Meanwhile, the above-described system can be applied to a toll road of a simple toll collecting system, or a parking area, wherein a gate is not present. That is, because a toll road of a simple toll collecting system and the like has no entrance, information on the vehicle-mounted apparatuses need not to be read out. For this reason, this system can be used only for reception of tolls or transfer of simple information such as parking time, time for passage, and the like, and the system of the present embodiment can easily be applied.

[0060]

[Effects of the Invention]

As described above, the invention set forth in claim 1 has an effect in that secrecy is independently maintained using different electronic keys and thus the security of the road-to-vehicle communication device can be improved.

[0061]

The invention set forth in claim 2 has an effect in that by providing each of the first encryption means and the road-side communication means, the second encryption means and the information transfer means, and the third encryption means and the vehicle-mounted

communication means on the same substrate, decoding of analysis and the like becomes difficult and the security of the road-to-vehicle communication device can be improved.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1]

Fig. 1 is a block diagram that shows an automatic toll receiving system to which the present invention is applicable.

[Fig. 2]

Fig. 2 is a schematic perspective view that shows a mid-route in the automatic toll receiving system.

[Fig. 3]

Fig. 3 is a block diagram that shows a vehicle-mounted apparatus of the present embodiment.

[Fig. 4]

Fig. 4 is a block diagram that shows one example of an on-road apparatus of the present embodiment.

[Fig. 5]

Fig. 5 is a block diagram that shows a structure of an IC card to which the present invention is applicable.

[Fig. 6]

Fig. 6 is a flow chart that shows a process routine of the information writing device.

[Fig. 7]

Fig. 7 is a flow chart that shows a process routine of the vehicle-mounted apparatus with respect to the information writing device.

[Fig. 8]

Fig. 8 is a flow chart that shows a communication processing routine of the vehicle-mounted apparatus.

[Fig. 9]

Fig. 9 is a flow chart that shows a process routine of the on-road apparatus.

[Fig. 10]

Fig. 10 is a flow chart that shows a process routine of the IC card.

[Fig. 11]

Fig. 11 is an image diagram showing transmitting and receiving of information, which is effected between the information writing device and the vehicle-mounted apparatus.

[Fig. 12]

Fig. 12 is an image diagram showing transmitting and receiving of information, which is effected between an IC card read/write device and the vehicle-mounted apparatus.

[Fig. 13]

Fig. 13 is an image diagram showing transmitting and receiving of information, which is effected between the on-road apparatus and the vehicle-mounted apparatus and between the IC card read/write device and the vehicle-mounted apparatus.

[Description of the Reference Numerals]

10: on-road apparatus

28: memory

30: vehicle-mounted apparatus

48: storage circuit

50: transmission circuit

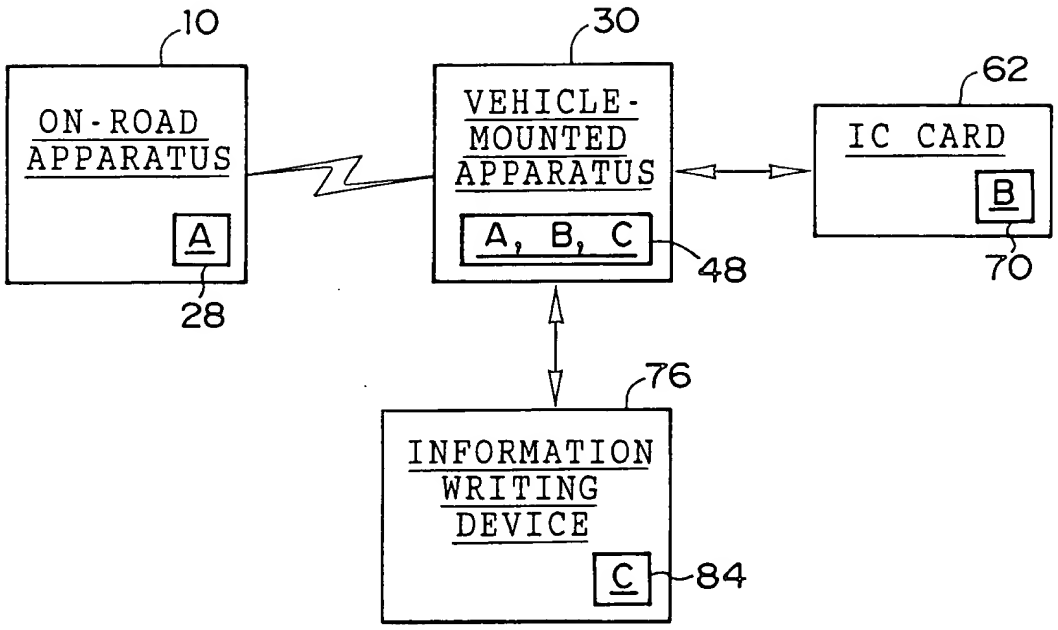
60: IC card read/write device

70: memory

76: information writing device

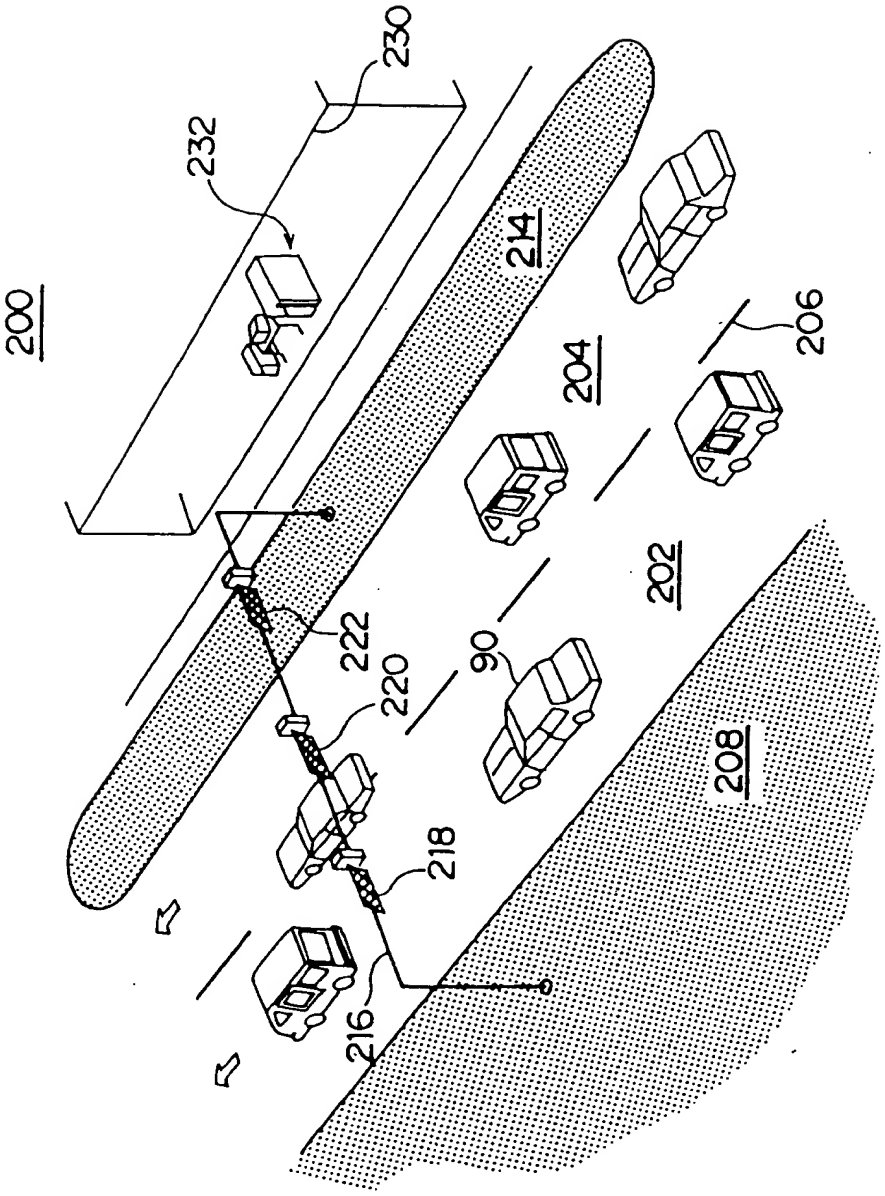
84: memory

[DOCUMENT NAME] DRAWINGS
[FIG. 1]

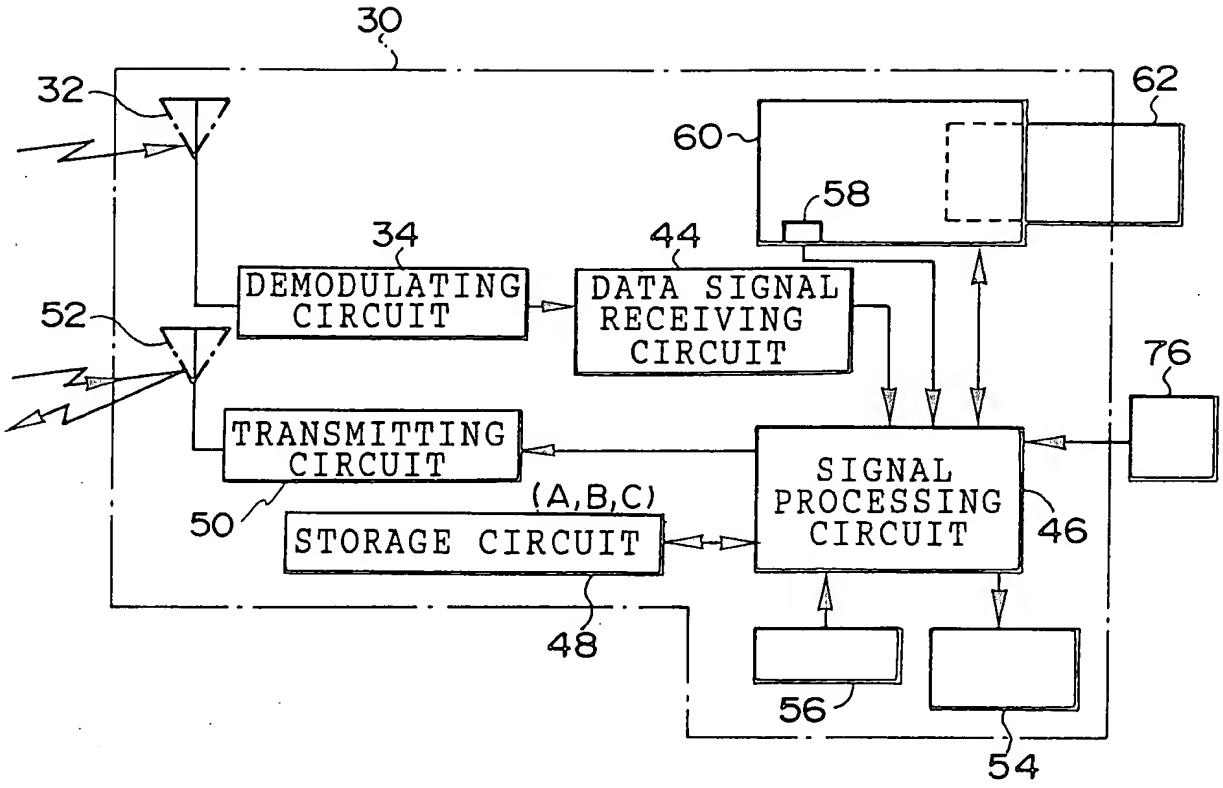


10: ON-ROAD APPARATUS
28: MEMORY
30: VEHICLE-MOUNTED APPARATUS
48: STORAGE CIRCUIT
70: MEMORY
76: INFORMATION WRITING DEVICE
84: MEMORY

[FIG. 2]

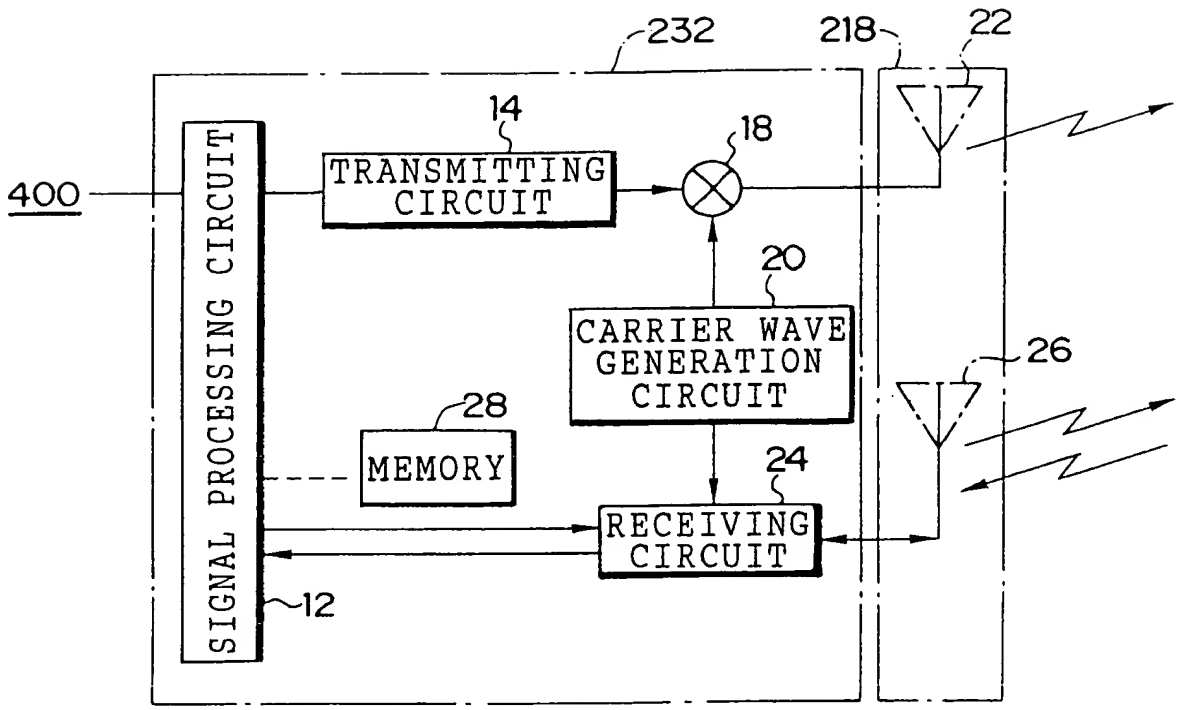


[FIG. 3]

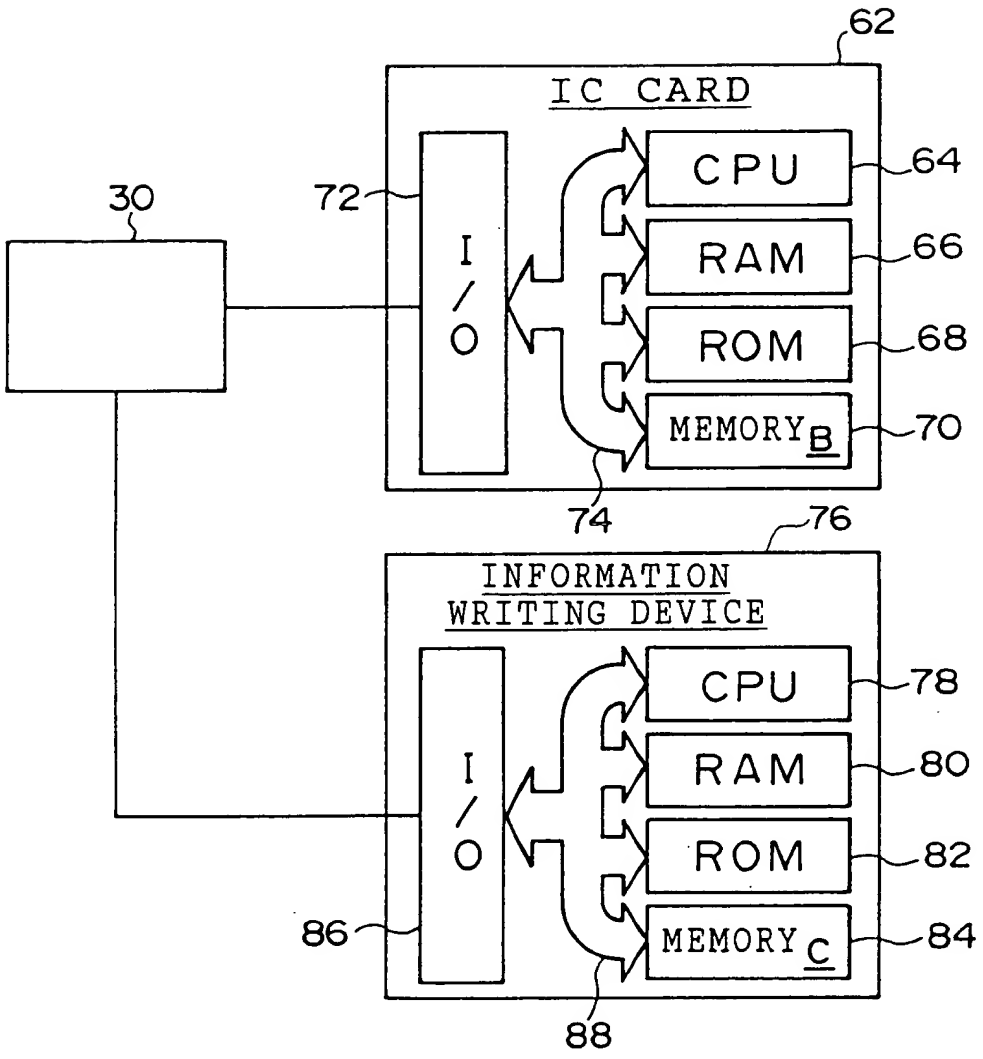


50: TRANSMISSION CIRCUIT
60: IC CARD READ/WRITE DEVICE

[FIG. 4]

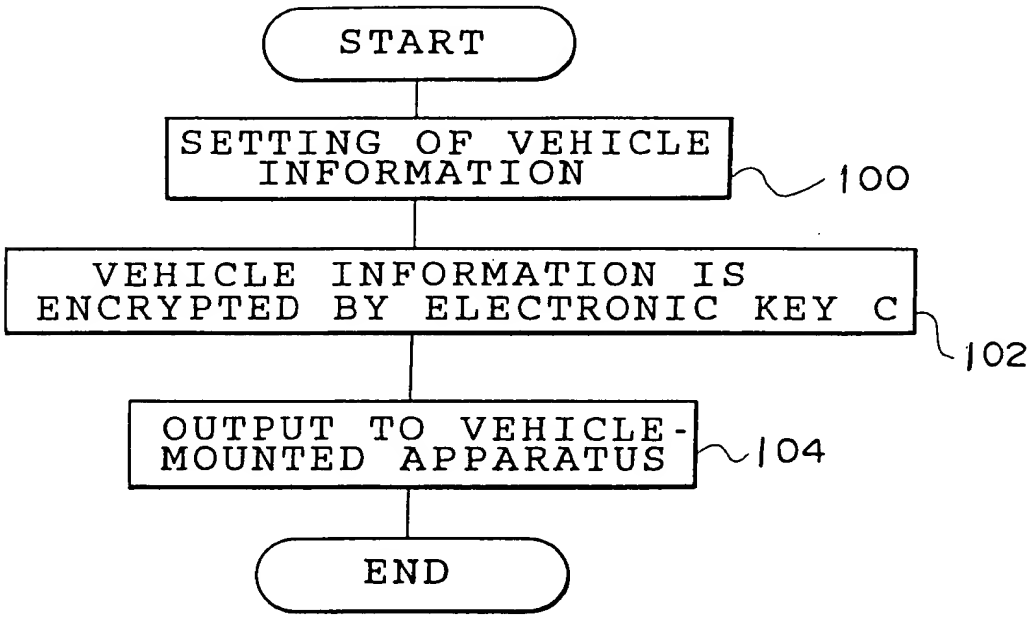

232
218
22
14
18
400
TRANSMITTING CIRCUIT
SIGNAL PROCESSING CIRCUIT
20
CARRIER WAVE GENERATION CIRCUIT
26
28
MEMORY
24
RECEIVING CIRCUIT
12

[FIG. 5]


62
IC CARD
CPU
64
RAM
66
ROM
68
MEMORY B
70
I/O
72
30
74
76
INFORMATION WRITING DEVICE
CPU
78
RAM
80
ROM
82
MEMORY C
84
I/O
86
88

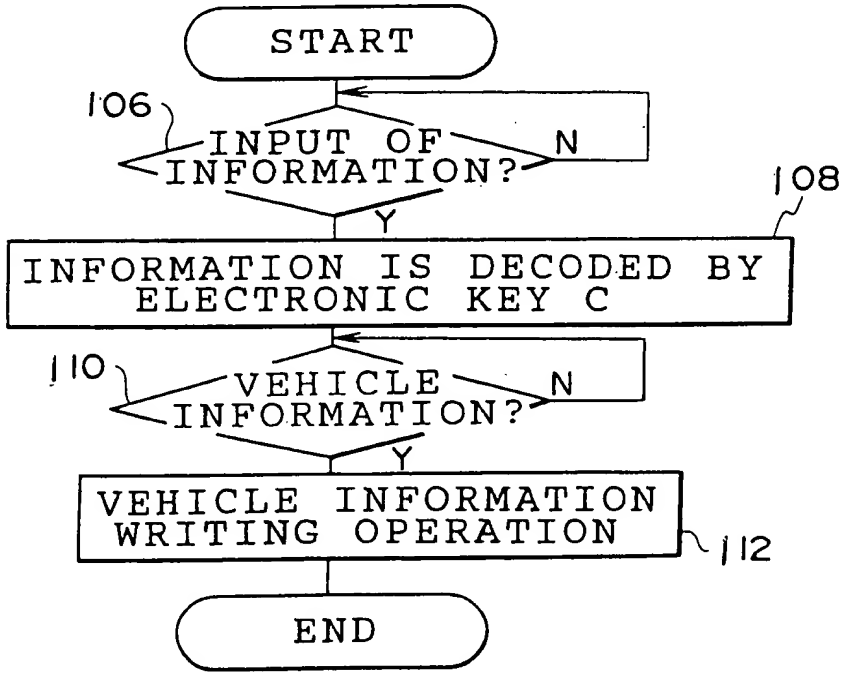
[FIG. 6]

PROCESS OF INFORMATION WRITING DEVICE



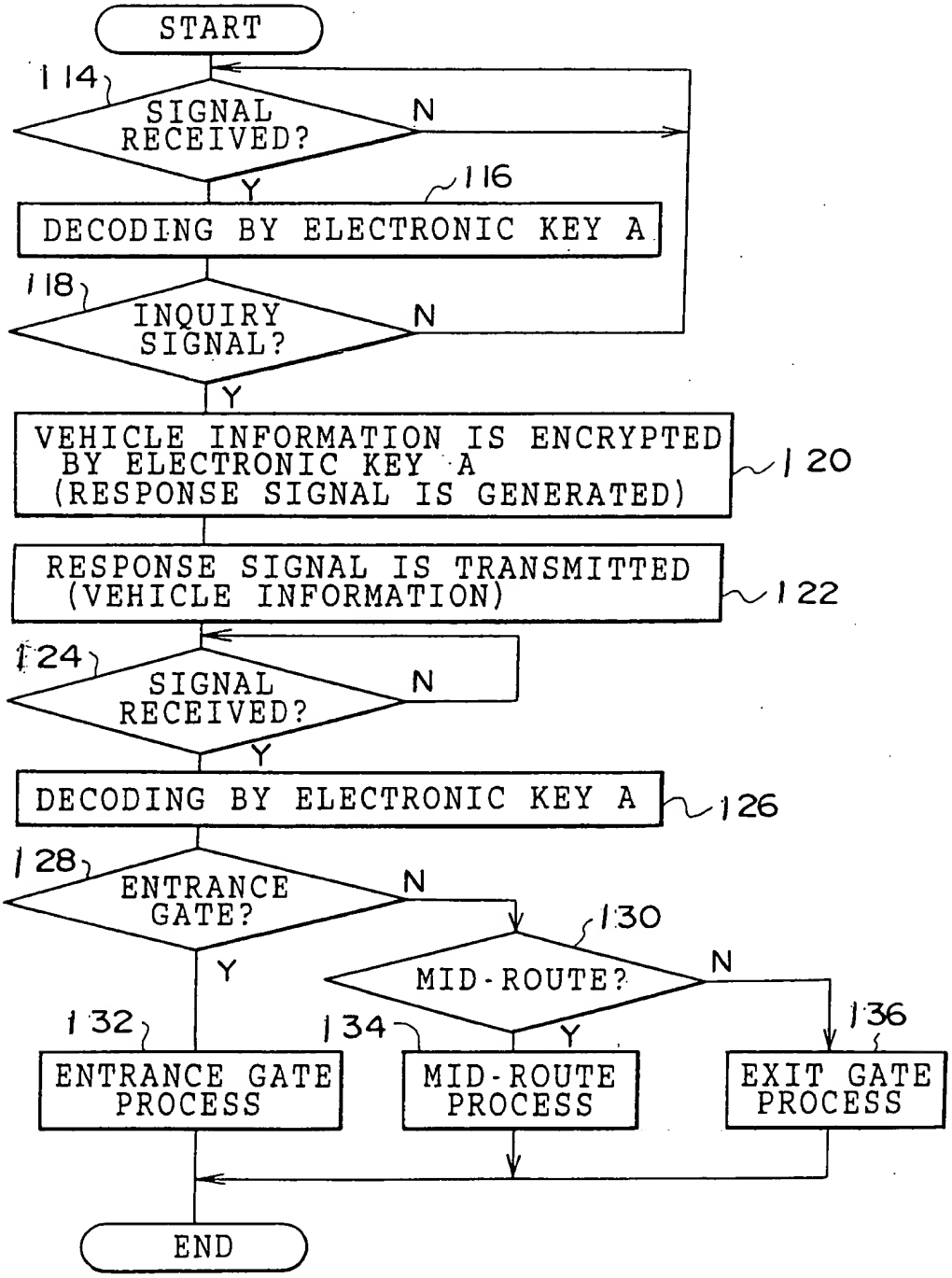
[FIG. 7]

PROCESS OF VEHICLE-MOUNTED APPARATUS



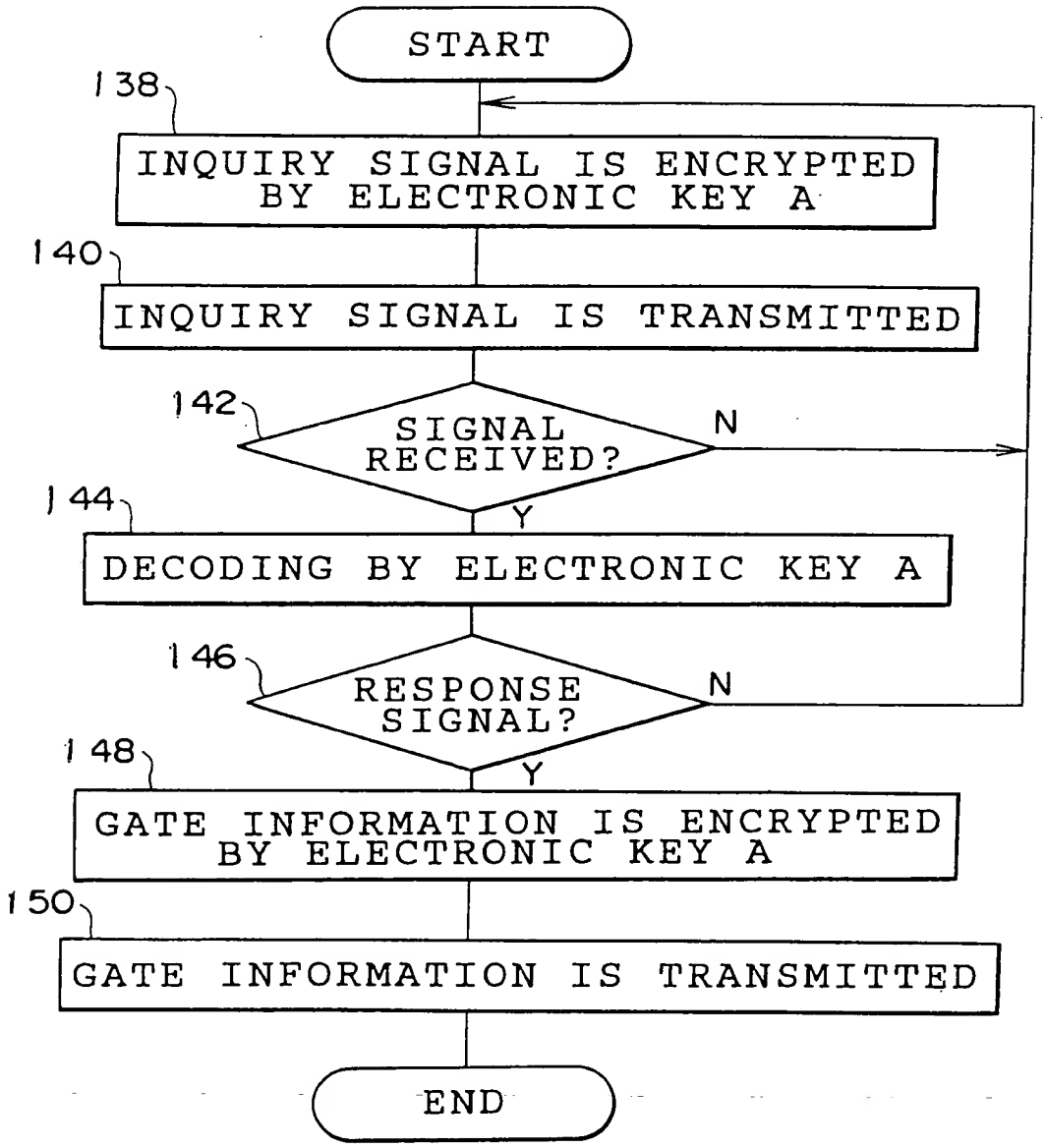
[FIG. 8]

COMMUNICATION PROCESS OF VEHICLE-MOUNTED APPARATUS

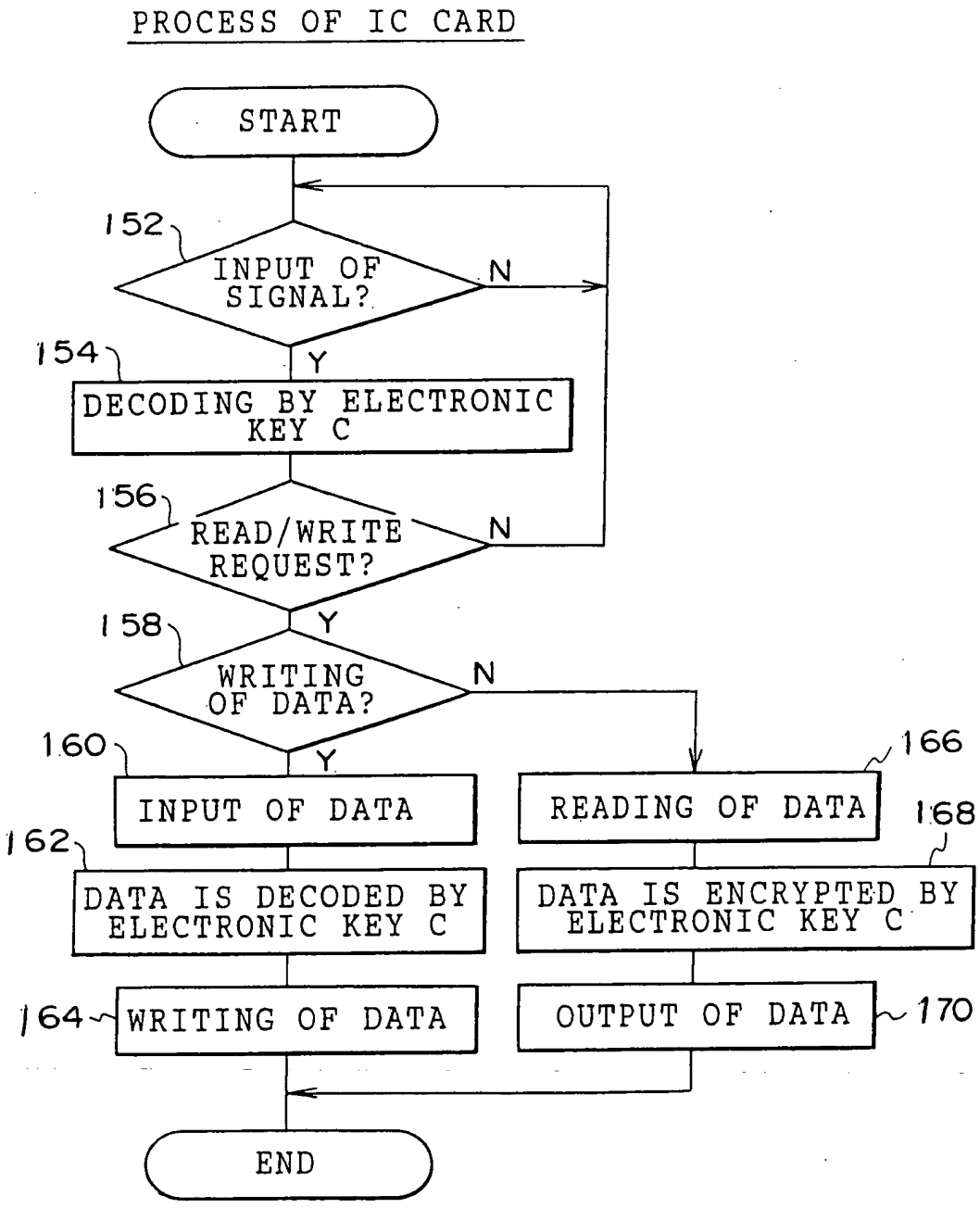


[FIG. 9]

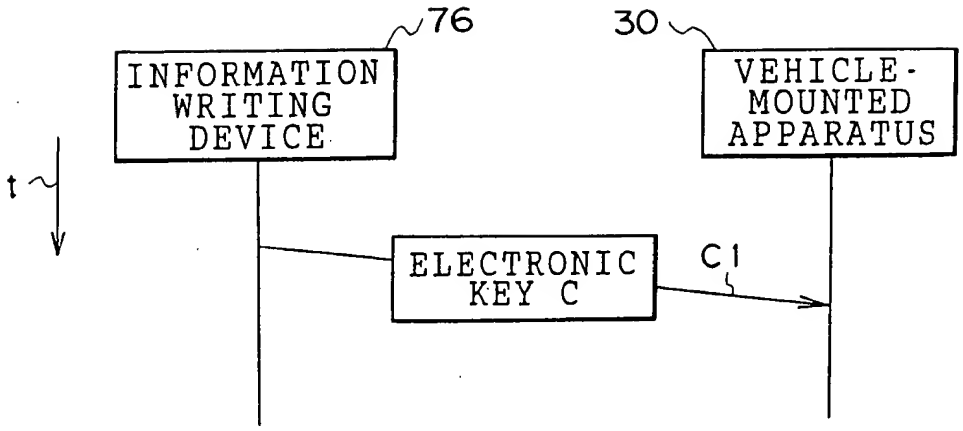
PROCESS OF ON-ROAD APPARATUS



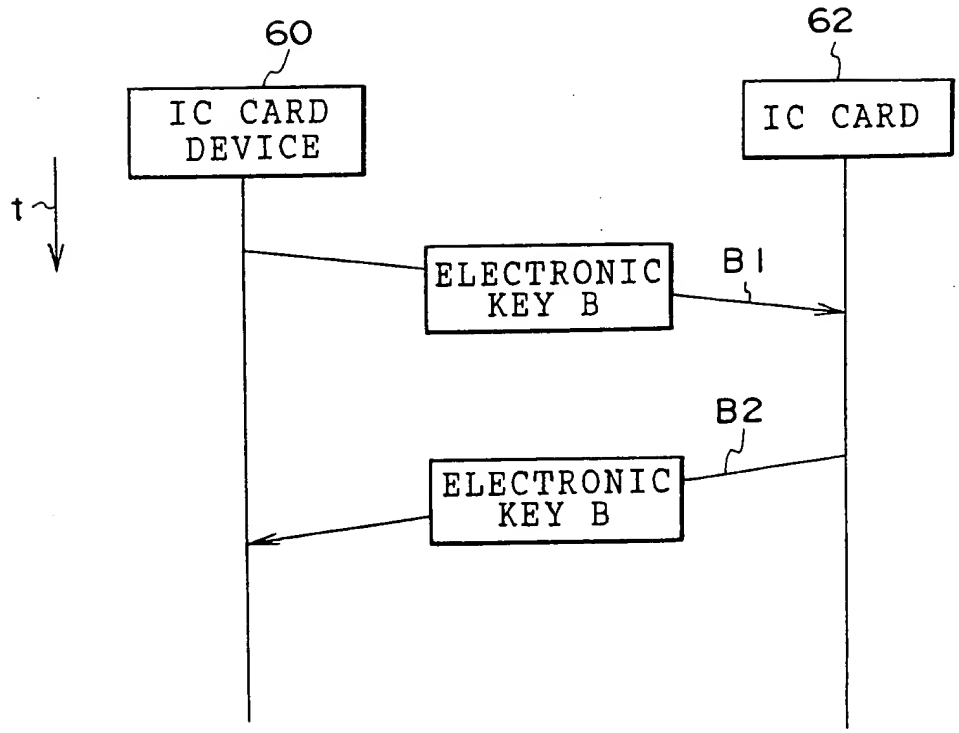
[FIG. 10]


PROCESS OF IC CARD
START
152
INPUT OF SIGNAL?
N
Y
154
DECODING BY ELECTRONIC KEY C
156
READ/WRITE REQUEST?
N
Y
158
WRITING OF DATA?
N
Y
160
INPUT OF DATA
162
DATA IS DECODED BY ELECTRONIC KEY C
164
WRITING OF DATA
166
READING OF DATA
168
DATA IS ENCRYPTED BY ELECTRONIC KEY C
170
OUTPUT OF DATA
END

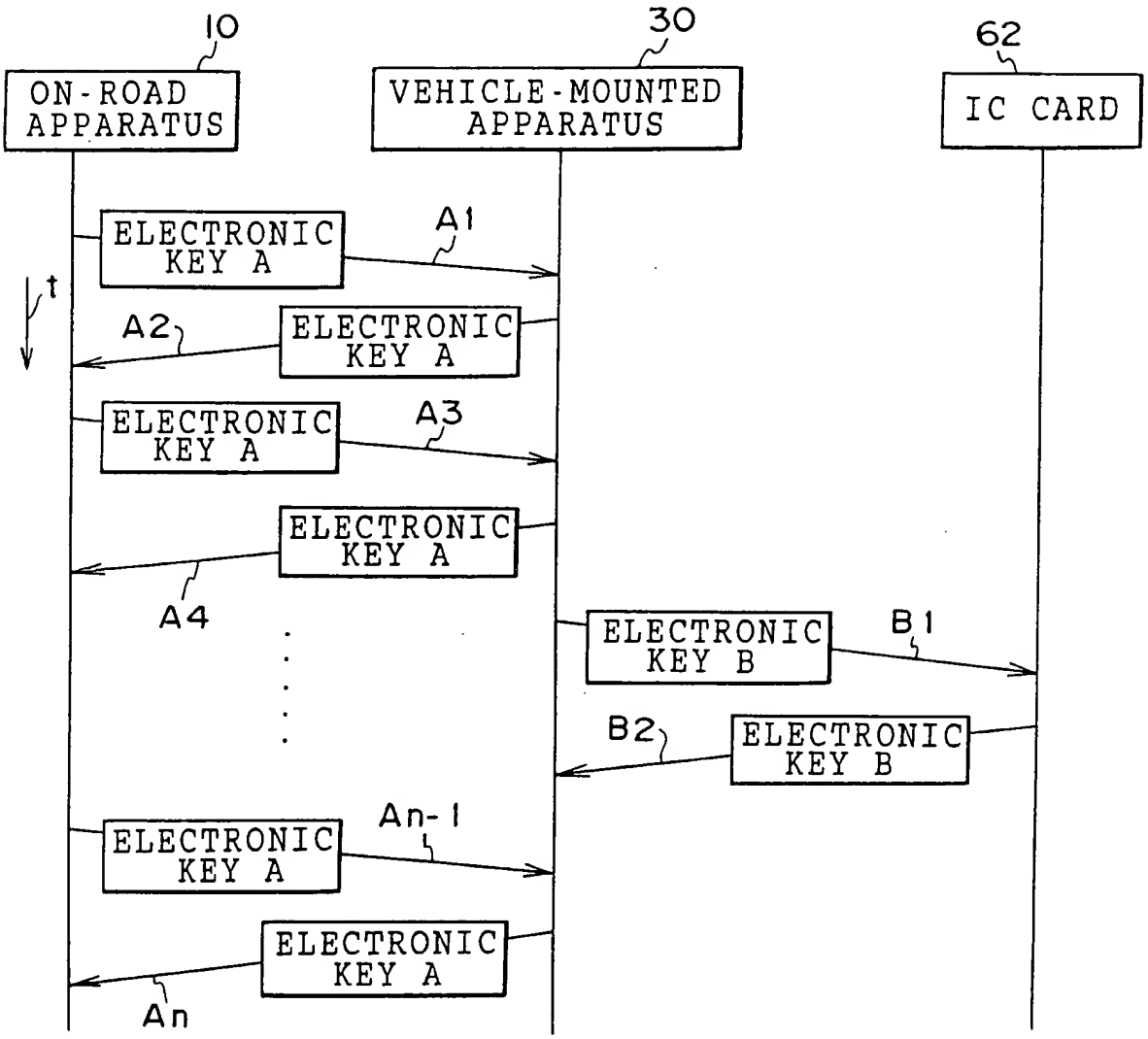
[FIG. 11]


76
30
INFORMATION WRITING DEVICE
VEHICLE-MOUNTED APPARATUS
t
ELECTRONIC KEY C
C1

[FIG. 12]


60
IC CARD DEVICE
62
IC CARD
t
ELECTRONIC KEY B
B1
B2
ELECTRONIC KEY B

[FIG. 13]


10
ON-ROAD APPARATUS
30
VEHICLE-MOUNTED APPARATUS
62
IC CARD
ELECTRONIC KEY A
A1
t
A2
ELECTRONIC KEY A
ELECTRONIC KEY A
A3
ELECTRONIC KEY A
A4
ELECTRONIC KEY B
B1
B2
ELECTRONIC KEY B
An-1
ELECTRONIC KEY A
ELECTRONIC KEY A
An

[DOCUMENT NAME] ABSTRACT OF THE DISCLOSURE

[SUMMARY]

[OBJECT]

To provide a road-to-vehicle communication device, that can improve security using a simple structure and in a simple manner.

[MEANS FOR SOLUTION]

Information encrypted using an electronic key A is intercommunicated through radio communication between an on-road apparatus 10, which is provided on a road side and includes a memory 28 storing the electronic key A, and a vehicle-mounted apparatus 30, which is provided on a vehicle and includes a storage circuit 48 storing electronic keys A, B and C. Information encrypted using the electronic key B is intercommunicated between the vehicle-mounted apparatus 30 and an IC card 62 which includes a memory 70 storing the electronic key B. Information encrypted using the electronic key C is intercommunicated between the vehicle-mounted apparatus 30 and an information writing device 76 which includes a memory 84 storing the electronic key C. Because information is sent and received in a encrypted manner using different electronic keys, security of the system can be improved.